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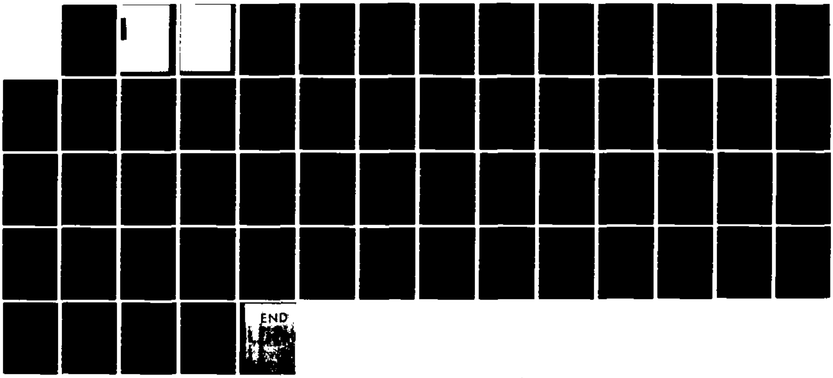

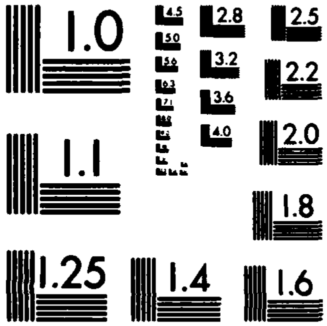

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For many years, large reservoirs have been constructed throughout the United States to provide flood control, power sources, and recreation areas. Design and operational characteristics of these reservoirs determine the types of habitat available to fish and wildlife species.

Periodic fluctuations in water level on reservoirs are of particular concern to natural resource managers. The seasonal fluctuations that occur

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on many lakes and flood-control reservoirs and the daily fluctuations that are necessary on some hydroelectric projects often result in elimination of shoreline vegetation, which causes erosion, diminished water quality, and habitat loss or degradation.

This report presents abstracts of papers presented at a workshop organized to identify the problems resource managers face and to present research results that might be applied to alleviate or moderate the adverse effects of reservoir fluctuation. Sessions were organized under the general topics of vegetation, wildlife, and fisheries.

Discussions of the results of the workshop sessions and possible means of resolving conflicts between the requirements of the reservoir biota and the principal operational goals of the reservoir projects are also presented. Addresses of the principal authors are provided to allow readers to seek further information regarding particular studies.

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PREFACE

This report summarizes the proceedings of a workshop on the environmental effects of reservoir water level fluctuations. The workshop was held at the U. S. Army Engineer Waterways Experiment Station (WES) on 24-26 February 1981, as part of the Environmental and Water Quality Operational Studies (EWQOS) Program.

In addition to the individual speakers whose abstracts are published here, a number of people helped to organize the workshop and prepared this report. The workshop was organized and moderated and this report was edited by Mr. Hollis H. Allen, Environmental Laboratory (EL), WES, and Dr. Larry R. Aggus, National Reservoir Research Program, U. S. Fish and Wildlife Service, Fayetteville, Arkansas. Dr. Aggus summarized the fisheries workshop sessions and provided the discussion of operational and administrative constraints. Mr. Charles V. Klimas (EL) summarized the vegetation and wildlife workshop sessions. Other EL personnel who contributed to this effort include Mr. Charles J. Newling, Dr. Randall K. Stocker, Dr. John Nestler, Dr. Kenneth T. Ridlehuber, Mr. James W. Teaford, and Mr. Harvey L. Jones.

This work was performed under the direct supervision of Dr. Hanley K. Smith, Wetland and Terrestrial Habitat Group, EL; and under the general supervision of Dr. Conrad J. Kirby, Jr., Chief, Environmental Resources Division, EL; and Dr. John Harrison, Chief, EL, WES. Program Manager for EWQOS was Dr. Jerome L. Mahloch, EL. Mr. John Bushman, Planning Division, Office, Chief of Engineers, was the Technical Monitor for this Work Unit (EWQOS IIE.1).

Commander and Director of WES during the publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. Fred R. Brown.

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CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENTS

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
acres	4046.873	square metres
feet	0.3048	metres
inches	0.0254	metres

EFFECTS OF FLUCTUATING RESERVOIR WATER LEVELS ON FISHERIES, WILDLIFE, AND VEGETATION; SUMMARY OF A WORKSHOP, 24-26 FEBRUARY 1981

INTRODUCTION

The Problem

Large reservoirs designed for flood control, power production, recreation, and other purposes have been constructed in nearly every part of the country. As these water bodies have become commonplace, they have assumed an important role in determining the types of habitat available to many fish and wildlife species on a regional and national scale. In recent years, natural resource managers have become increasingly concerned with one aspect of reservoir operations that presents unique and difficult problems: the periodic fluctuations in water level that typically occur on many of these lakes. Whether the fluctuations are seasonal (as on many flood-control reservoirs) or daily (as on some hydroelectric projects) often the elimination of shoreline vegetation results in erosion, diminished water quality, and habitat loss or degradation.

The Workshop

The seriousness of this problem has been demonstrated by the interest generated by this workshop. Over 60 people attended the three-day meeting, including representatives of the U. S. Fish and Wildlife Service, Army Corps of Engineers, Forest Service, Soil Conservation Service, Tennessee Valley Authority, Federal Energy Regulatory Commission, resource agencies of 10 states, and representatives from universities and consulting firms. The workshop was originally proposed in response to the high degree of concern among Corps resource managers; an informal 1977 survey indicated that 65 percent of the Corps' 32 Districts had significant problems related to fluctuating water levels.

Perhaps the greatest part of this concern is related to the fishery resource. According to a 1975 survey of fish and wildlife related recreation, over 25 percent of all freshwater angling in the United States occurred on reservoirs and approximately $2.6 billion were spent in that pursuit.

Purpose and Scope

In light of such national interest, this workshop was organized to define the problems resource managers face and to present research results that might alleviate or moderate the adverse effects of reservoir fluctuation. Researchers were invited to present results of recent studies or describe case histories of specific attempts to mitigate or reduce habitat losses related to reservoir water-level fluctuation. Following presentation of the invited papers, the speakers and attendees formed smaller workshop groups to discuss particular problems and identify promising approaches toward alleviating them. These workshop sessions were organized under the general topics of vegetation, wildlife, and fisheries. A final discussion session brought all participants together to summarize results of the workshops and possible means of resolving conflicts between the requirements of the reservoir biota and the principal operational goals of the reservoir projects.

Since the workshop discussions and presented papers covered a variety of disciplines and geographic areas, this report is intended to be a simple summary and source for locating additional information rather than a formal proceedings; therefore a short abstract of each presented paper is reproduced here in lieu of the full text. Addresses of principal authors are provided to allow readers to seek further information for particular studies. In addition, selected information gleaned from the paper sessions has been combined with highlights of the workshop sessions to produce summaries of the state and direction of research and management needs in each of the three principal topic areas. As these summaries indicate, concerns and levels of understanding vary widely among disciplines. Many of those involved in shoreline revegetation

research feel confident they can successfully vegetate many denuded areas if resource agency sponsorship becomes available. Wildlife managers support the goal of shoreline revegetation, but some are turning their attention to satellite impoundments and subimpoundments as a means of maintaining control over desired habitat manipulations. Finally, fisheries researchers and managers have been working with reservoir habitats in greater detail and for a longer period than either of the other two disciplines, and this is reflected in the longer, more detailed summary in this report. The fisheries summary also includes a discussion of operational constraints and related issues that must be considered in any attempt to modify existing water-level manipulation schedules.

Although the workshop was organized primarily to allow researchers and managers to meet and discuss various problems and possible solutions, the editors believe this report also will be of value to those who were unable to attend. By making readers aware of recent and ongoing research and by highlighting ideas and suggestions that arose during the workshop sessions, we hope to stimulate new and innovative approaches to individual resource management problems.

ABSTRACTS OF
PAPERS PRESENTED

ANALYSIS OF LAKE-LEVEL INFLUENCE ON VEGETATION IN LAKE CHAMPLAIN

William D. Countryman*

ABSTRACT

Lake Champlain in Vermont, New York, and Quebec, Canada, experiences normal annual fluctuations of elevation in the range of 5 ft.** Periodically, the upper elevation will increase by another 3 ft with consequent property loss, both on the lakeshore and along the outlet stream--the north-flowing Richelieu River in Quebec. A combination of lakeshore/riverbank development and abnormally high water levels since 1969 has renewed calls for artificial regulation of lake levels and riverflows.

Following an expenditure of $2.6 million in economic, engineering, and environmental studies and hearings, an International Champlain-Richelieu Board has recommended to the U. S.-Canada International Joint Commission that a combination of structural and nonstructural measures be used to limit flood losses. Regulation under these recommendations would be attuned to environmental needs, especially for the 52,000 acres of wetlands adjoining the lake. The maximum estimated benefit/cost ratio would be 2.0. The proposal, actively opposed by the State of Vermont, would maintain 78 percent of the wetlands that exist under natural periodic high water maxima.

The purpose of 1976-1977 wetland studies was to determine the influence of lake level on aquatic and marsh vegetation. Forty-two wetlands were studied, eleven of them intensively. Transects were run perpendicular to the shore, and vascular plant and elevation data were recorded at 1-m intervals. Data were computer-reduced to determine the relative frequency of occurrence of species and their respective

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* Aquatec, Inc., 75 Green Mountain Drive, South Burlington, VT 05401.

** A table of factors for converting U. S. customary units of measurements to metric (SI) units is presented on page 3.

elevational distributions. Species with critical (i.e., narrow) elevation ranges and species that would be most adversely affected by prolonged abnormalities in lake levels were noted.

It was concluded that lake-level regulation would have little or no impact on submersed and floating plants. Emergent vegetation would be little affected except by extreme lake-level regulation. Swamp forests were observed in a limited elevation range of only about 1 m. These forests would be somewhat diminished by even moderate water-level regulation, for they owe their perpetuation not only to favorable soil water conditions but also to a forest floor with little plant competition for seedlings (i.e., areas not favorable for sedges and grasses). The most sensitive and the least extensive wetland type in this area is the grass and sedge meadow. These meadows owe their existence to seasonally or periodically flooded damp soils. It is on these areas in early spring floods that northern pike and other esosids spawn. Later in the season when waters recede, these areas are often grazed or even mowed.

Greater regulation of lake levels would lead to a change in plant communities, especially in the grass and sedge meadows and swamp forests, and, in all likelihood, to urban development of one kind or another.

MANAGEMENT OF AQUATIC AND WETLAND VEGETATION BY REGULATING WATER LEVELS

A. Leon Bates,* W. Michael Dennis, and David H. Webb

ABSTRACT

Extensive expanses of periodically exposed shoreline area (variously described as drawdown zones, eulittoral zones, mudflats, or reservoir margins) occur within the upper levels of regulated impoundments. In contrast to dewatered zones around the margins of natural lakes that occur in response to seasonal variations in precipitation, the drawdown zones of man-made impoundments are subjected to variable periods of inundation based on the optimum water-level manipulation for the impoundment's use (e.g., flood control, navigation, recreation). Hydrarch development of aquatic and wetland vegetation in these zones is determined by the timing, duration, and magnitude of the flooding regime. Within aquatic habitats in the mid South, the ecesis of aquatic macrophytes from the permanent pool through the drawdown zone generally occurs in a predictable pattern; although species composition may vary from year to year, the annual and perennial plants tend to occupy the same relative contour zones. A typical progression of dominance, from native, submersed macrophytes within the permanent pool to emergents of the shoreline transition zone of regulated reservoirs in the mid South, would include genera such as:

Potamogeton ⟶ *Nelumbo* ⟶ *Eleocharis* ⟶ *Eragrostis* ⟶ *Cyperus*

Cephalanthus ⟶ *Justicia* ⟶ *Juncus* ⟶ *Typha* ⟶ *Salix*.

The capability to manage vegetation is enhanced by the ability to regulate the timing of flooding and the water level. Water-level management schemes can be developed which encourage establishment of desirable innocuous macrophytes and reduce nuisance aquatic weeds. Controlled

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* Tennessee Valley Authority, Muscle Shoals, AL 35660.

manipulations that result in a stable pool are conducive to proliferation of submersed macrophytes and provide optimum conditions for noxious exotic submersed species such as Eurasian watermilfoil (*Myriophyllum spicatum* L.) and spiny-leaf naiad (*Najas minor* L.).

Artificial establishment of water-tolerant woody plants such as bald-cypress (*Taxodium distichum* [L.] Richard) has been used to alter herbaceous, emergent, wetland communities in the upper shoreline zone. Attempts also have been made to allow existing water-tolerant woody plants to remain in areas to be flooded in newly constructed impoundments. Other cultural practices, such as annual shoreline conditioning by mechanical mowing, are used to maintain associations of pioneer emergent macrophytes that provide diverse and productive habitats for the wildlife and fisheries resources. Studies relating to the identification and phenology of aquatic and wetland plants have been fundamental in determining responses to fluctuating water levels, especially if the fluctuations are manipulated and artificial.

RESERVOIR REVEGETATION RESEARCH IN CALIFORNIA

Andrew T. Leiser*

ABSTRACT

Since 1969, the Department of Environmental Horticulture, University of California, Davis, has been engaged in screening plant materials for revegetation of reservoir drawdown areas. The purposes of the research were to explore the feasibility of vegetating these areas for recreational use, fish habitat, and aesthetic purposes. Funding has been from several agencies: U. S. Bureau of Reclamation, U. S. Army Corps of Engineers, and California Department of Fish and Game. Approximately 70 woody and 10 herbaceous accessions have been screened, including California natives and eastern United States and Australian species. Survival data, by depth and time of inundation, and limited growth data are given. Limited numbers of individuals of several species have survived over 120 days and 20 ft of inundation. Good survival of many species for an establishment period has been obtained at 62 days and 12 ft of inundation. Some cost data on propagation, planting, and first-year maintenance are given. Supporting agencies have begun experimental planting of several native species at a number of reservoirs.

* Department of Environmental Horticulture, University of California, Davis, CA 95616.

PRELIMINARY REPORT OF FLOOD TOLERANCE OF 10 HERBACEOUS SPECIES TRANSPLANTED AT LAKE TEXOMA, OKLAHOMA

James E. Lester* and James R. Bankston

ABSTRACT

Flood tolerance of 10 herbaceous species was measured at two sites during the summer of 1979. Western wheatgrass (*Agropyron smithii*), giant reed (*Arundo donax*), buffalo grass (*Buchloe dactyloides*), yellow nutgrass (*Cyperus esculentus*), maidencane (*Panicum hemitomon* T2812), vine mesquite (*Panicum obtusum*), Kanlow switchgrass (*Panicum virgatum*), common reed (*Phragmites australis*), prairie cordgrass (*Spartina pectinata*), and eastern gamagrass (*Tripsacum dactyloides*) were transplanted in the spring of 1979 at a control pool near Lake Texoma and on a shoreline site at Lake Texoma.

At both sites, the 10 species were randomly transplanted in equal numbers in elevational tiers (treatment level) grouped into blocks (replication). During the summer, transplant success was measured at eight treatment levels (inundation periods). At the control pool, the elevational tiers of each of the three blocks were inundated for 0, 2, 4, and 6 weeks, respectively. Survival after treatment of 1200 individuals transplanted at the pool was 0, 100, 100, 100, 75, 85, 100, 100, 85, and 50 percent, respectively, for the species listed above. The shoreline transplants were subjected to five uncontrolled treatment levels. The treatments included 1, 2, 5, 10, and 20 weeks of inundation during the 1979 growing season. Survival of the 200 individuals of each species after treatment was 5, 80, 60, 60, 50, 60, 70, 90, 45, and 55 percent, respectively, for the species listed above.

In addition to survival, five other parameters were used to

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* Department of Biology, Southeastern Oklahoma State University, Durant, OK 74701 (paper presented by Mr. Bankston, same address).

measure success after treatment. They included percent cover, stem density, average height, vigor, and phenology.

Soil and water samples were taken at both sites. A preliminary soil test established fertilization rates. Other soil and water samples were collected concurrently with plant measurement.

STUDIES ON VEGETATION ESTABLISHMENT IN THE DRAWDOWN AREAS OF LAKE WALLULA AND A CONTROLLED POOL AT McNARY DAM, OREGON

R. D. Comes*

ABSTRACT

In the early summer of 1979, 10 woody and 15 herbaceous species were transplanted at two sites on the south shore of Lake Wallula and at an artificial impoundment near McNary Dam on the Columbia River. All species were planted on three or four contours with a vertical distance of 0.25 to 1.5 ft between contours at the different sites. Water depth at the shoreline sites usually fluctuated daily, but the amplitude varied from day to day. At the control pool, the water level fluctuated 4.5 ft daily. Soils at the experimental sites ranged from sand to sandy loam, contained 0.1 to 0.5 percent organic matter, and had a pH of 7.4 to 9.2 and a cation exchange capacity of 4.8 to 10.6 meq/100 g.

Within 2 weeks after planting, one shoreline site, established on a sandy beach area, was devastated by a strong wind and the resultant wave energy. At the other sites, survival of both herbaceous and woody species was greater at the control pool, where water-level fluctuations were greater and complete (plants exposed to the atmosphere for various periods), than at the shoreline sites, where the fluctuations were irregular and not always complete. In general, plant survival and cover increased as the depth of flooding decreased. *Elocharis coloradoensis* was a notable exception to this generalization. Surviving on all contours at the control pool were 78 to 100 percent of *Deschampsia caespitosa*, *Eleocharis ovata*, and *Carex aperta* plants. Three *Eleocharis* species (*palustris*, *coloradoensis*, and *ovata*), *Carex aperta*, and *Scirpus validus* were the only species that flowered.

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* U. S. Department of Agriculture, Science and Education Administration, P. O. Box 30, Prosser, WA 99350 (paper presented by Mr. Tim McCreary, same address).

Moderate to dense populations of filamentous algae are suspected of having an adverse effect on plant vigor and survival at one shoreline site. Fungal disease(s) reduced the vigor and probably contributed to the death of some *Scirpus validus* and *S. americanus* plants, and a pH-induced iron chlorosis decreased the vigor of several species at the control pool. Waterfowl selectively extirpated all *Eleocharis coloradoensis* plants on the uppermost flooded contour at the control pool. Gophers, beaver, muskrats, and filamentous algae are believed to have had a negative effect on survival and growth of several species.

PLANT PROCUREMENT AND PROPAGATION FOR REVEGETATION OF RESERVOIR SHORELINES, WITH PARTICULAR REFERENCE TO LAKE WALLULA, COLUMBIA RIVER, OREGON AND WASHINGTON

Wilber E. Ternyik*

ABSTRACT

Marsh and shoreline vegetation establishment on the reservoirs of the Pacific Northwest has to date met with minimum success. However, research efforts started in 1979 at Wallula Reservoir on the Columbia River represent a major step in stabilization and revegetation of reservoir drawdown areas. This project is being conducted by the U. S. Army Engineer Waterways Experiment Station, in cooperation with the U. S. Fish and Wildlife Service. The objective of the study is to identify and establish vegetation in an environment which experiences 3- to 5-ft daily fluctuations in water level and up to 3-ft fluctuation of ice cover during winter. The ultimate goal is to provide wildlife habitat and stabilize shorelines of Lake Wallula.

Three sites, two on the shoreline and one within an experimental pool, were selected for revegetation studies using 15 herbaceous species and 10 woody species. Most plant species were located and collected throughout Oregon with the remainder being purchased from commercial nursery sources. Planting stock was maintained in near-dormant conditions prior to transport to the study site. Due to delays at the site, temporary storage facilities were constructed and some unavoidable losses occurred. Study sites were staked, fertilized, and planted during June and July 1979, with some sites requiring fencing and irrigation.

Additional species were added in June 1980, and new planting techniques were used at one site in an attempt to overcome high wave energy problems. Treatments used were reed rolls containing three herbaceous plant species, willow mats firmly laced together and anchored with steel

* Wave Beach Grass Nursery, 921 Rhododendron Dr., Florence, Or 97439.

rods, and willow facines 10 ft in length buried at 2- to 4-in. depths. Irrigation was applied for 6 weeks as needed.

Throughout this effort, detailed records were maintained concerning plant selection criteria, propagation methods, plant storage, and costs. The results of this effort will assist in identifying plant species suitable for shoreline revegetation efforts and in determining the feasibility of such efforts in the future.

WILDLIFE HABITAT MANAGEMENT ALONG RESERVOIR INUNDATION ZONES

Dale K. Fowler*

ABSTRACT

Large expanses of drawdown zones on multipurpose flood-storage reservoirs are exposed for a significant portion of the year and represent potential food producing lands for upland wildlife and waterfowl populations. This paper summarizes several wildlife oriented studies conducted along the drawdown zones of TVA tributary reservoirs and discusses the economic and ecological implications of conducting annual seeding operations on these lands. Constraints to establishing vegetation along drawdown zones include: availability of plant nutrients, growing season length, unscheduled water-level fluctuations, competition from naturally occurring vegetation, lack of suitable plant materials and seeding equipment, and monetary limitations. The economics and logistic feasibility of seeding drawdown zones by barge-mounted hydroseeder, air cushion vehicle, and helicopter are presented. The potential impacts of periodic shoreline seeding program on wildlife populations are discussed with emphasis on quantitative documentation of white tailed deer's (*Odocoileus virginianus*) use of seeded drawdown zone for forage. More work is needed, but it appears that exposed inundation zones can be manipulated to benefit selected wildlife populations.

* Division of Land and Forest Resources, Office of Natural Resources, Tennessee Valley Authority, Norris, TN 37828.

FACTORS INFLUENCING PRODUCTION AND UTILIZATION OF MOIST-SOIL FOODS

Leigh H. Frederickson* and Mark W. Sayre

ABSTRACT

Moist-soil plants are associated with mudflat environments and provide wildlife managers with the potential for natural food production with minimal dollar and energy expenditures, once management areas are developed. Moist-soil foods are desirable, attracting a diversity of wildlife and providing energy and many essential nutrients. Plant composition on moist-soil areas is determined by successional stage, date of water removal, duration of drawdown, turbidity, and summer and fall flooding. Early in succession, annuals generally are the best seed producers. Smartweeds respond well to early season drawdowns following soil disturbance or extended periods of flooding. Mid to late season drawdowns made early in succession favor millets, whereas panic grasses, crab grasses, stick tights, and sprangletop consistently appear after late season drawdowns. Sites with shallow clear surface water may produce dense stands of red-rooted sedges. As succession continues, woody growth and perennials appear, including some excellent seed producers. Food, water depth, and vegetation structure are important factors that influence wildlife use. Shorebirds prefer mudflats or shallow water with low and sparse vegetation, whereas rails prefer tall dense vegetation with water depths from 5 to 10 cm. Herons and other wading birds favor deeper water, 7 to 12 cm. Waterfowl will move into and feed in dense cover, but only if openings are available. Dabblers concentrate in shallow water, 10 to 25 cm, with mallards favoring the shallowest areas. Divers respond best to flooded sites where water is at least 25 cm deep.

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* University of Missouri - Columbia, Gaylord Memorial Laboratory, Puxico, MO 63960 (paper presented by Dr. Sayre, same address).

WATER FLUCTUATIONS AND COLUMBIA RIVER AVIFAUNA: HAZARDS, BENEFITS, AND CONFOUNDING FACTORS

Bruce C. Thompson*

ABSTRACT

The 11 dams on the Columbia River were constructed over a 30-year period from the late 1930's to the late 1960's. Structural and operational changes associated with increased power production continue to the present. Water fluctuation regimes superimposed on this dynamic system complicate the statement of definitive impacts on wildlife. The effects of power-peaking fluctuations on avifauna were studied on the Columbia River during 1976-1978. Examination of breeding chronologies and nest elevations of colonial waterbirds, waterfowl, and upland gamebirds revealed that active nests of at least eight species occurred within predicted future fluctuation zones between early February and mid-July. Bank erosion continually decreases available banks and island rims used by nesting swallows and Canada geese. Geese with broods spent 40 to 60 percent of daylight hours feeding, and predicted inundation of important brooding sites could energetically stress displaced broods. Wintering waterfowl used the reservoirs primarily for loafing, mostly on island edges and periodically exposed shoals. Wintering ducks and geese generally did not depend on river-associated food, but the Cassimer Bar area in Wells Reservoir was a notable exception serving as an important feeding and loafing area that deserves special consideration. Diversity and abundance of birds in riparian habitats were not different between fluctuating and nonfluctuating areas, but differences were found in species composition. Riparian areas subject to future inundation appeared more important to imported gamebirds than to native forms. Recommended mitigation measures should be directed at water-level regulation

* Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744.

during critical use periods and management of subimpoundments, islands, and shoreline use areas. Recently intensified agricultural operations adjacent to the Columbia River are beneficial to some avian species and may indirectly mitigate some impacts.

IMPACT OF FLUCTUATING WATER LEVELS ON FOODS CONSUMED BY BREEDING WATERFOWL

George A. Swanson*

ABSTRACT

Feeding ecology studies of breeding waterfowl were undertaken in south central North Dakota to provide a data base that could be used to assess the ecological relationships between aquatic habitat and breeding waterfowl. Foods of laying female dabbling ducks consisted largely of invertebrates: 99 percent in blue-winged teals (*Anas discors*) and shovelers (*A. clypeata*); 70 percent in mallards (*A. platyrhynchos*); 77 percent in pintails (*A. acuta*); and 72 percent in gadwalls (*A. strepera*). Food selection was influenced by the physiological demands and morphological adaptations of the bird, the behavior and ecology of the invertebrates selected as foods, and the general nature of the aquatic ecosystems as determined by basin morphology, hydrology, and climatic conditions.

Three-year-old female mallards and blue-winged teals were capable of producing five clutches of eggs on experimental ponds when high protein foods were abundant and available. Breeding birds responded to a reduction in food availability by extending renesting intervals, reducing clutch size, and terminating renesting efforts.

During the spring and early summer, seasonally flooded zones were important to breeding birds because they provided abundant and readily available, high protein animal foods. Later in the summer when seasonal water began to dry up, insects began to emerge in the deep marsh and open-water zones and feeding intensity shifted to more permanent waters. Protection and maintenance of seasonally flooded wet meadow and shallow marsh zones provided ideal aquatic habitat for foods that are consumed by laying female dabbling ducks.

* U. S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, ND 58401.

WATER-LEVEL MANAGEMENT STRATEGIES FOR THE CENTRAL UNITED STATES

Calvin L. Groen*

ABSTRACT

Water-level management has been recognized as an important fisheries management tool in the central United States. Environmental and biological benefits attributed to water-level management include improved forage bases, increased growth of fishes, improved spawning conditions, improved fish population structures, improved water quality, improved reservoir aesthetics, and rough fish reduction. It must be recognized that individual bodies of water and especially waters of different geographic areas have different management objectives requiring a unique water-level management plan for optimum fisheries benefits. Strategies have varied from total reservoir drawdowns to controlled reservoir releases in order to stimulate tailwater fisheries and to improve spawning conditions downstream. A greater regional awareness has developed in implementing water-level management strategies that affect entire river systems.

Unfortunately, the role of biopolitics, at times, is ignored when developing water-level management plans. Socio-economic factors are not adequately addressed, and human attitudes are not molded to fit sound biological principles in an effort to more effectively manage our reservoir resources. There are many competing interests placing demands on the use of surface waters. Priority use of surface water has been extended primarily to power producers, navigational interests, municipalities, industry, agriculture, flood control, etc. These uses are authorized and described as "beneficial effects," while recreational and fishery interests are not adequately recognized in the operational procedures of reservoirs. More effort must be made to point out and demonstrate

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* Kansas Fish and Game Commission, Box 54A, Pratt, KS 67124.

wildlife and fisheries values. Proper preplanning is also needed to establish fisheries management as an authorized project purpose.

OVERVIEW OF FISHERIES MANAGEMENT IN FLUCTUATING RESERVOIRS IN THE NORTHWESTERN UNITED STATES

Quentin J. Stober*

ABSTRACT

Fish populations in northwest reservoirs are subjected to a wide variety of stresses due to water-level fluctuations. Annual hydrographs for cyclic storage, annual storage, run-of-river, and large offstream reservoirs were compared to indicate the magnitude and timing of characteristic drawdown cycles. Habitat requirements and spawning, incubation, and emergence times for the common game and nongame fishes were reviewed to determine those potentially limited by minimum water levels, generally occurring in April.

The kokanee salmon (*Oncorhynchus nerka*) spawn along shorelines in reservoirs and lakes. The period from fall spawning (October-November) to spring emergence (April-May) includes about 7 months, during which drawdown may interrupt the life cycle. Water-level management strategies needed for kokanee fry survival in some reservoirs are presently being developed. Lake whitefish utilize similar shoreline habitat for reproduction and are vulnerable during a five-month period from December to April. The burbot, with its winter spawning and spring incubation periods, is similarly vulnerable. The lake trout introduced into large natural lakes in the region are apparently not affected by present drawdown due to the greater depth of spawning.

Cutthroat and rainbow trout and kokanee salmon are selectively introduced into new reservoirs in an effort to establish resident populations. The natural production of these species is managed in storage reservoirs by maintaining spawner access to tributary streams. Dolly Varden char usually adapt as a part of this community. Historical drawdown regimes in one main-stem reservoir indicate that the exotic

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spring-spawning walleye has a more compatible reproductive environment than the previously abundant kokanee salmon. Nongame species (northern squawfish, peamouth, redside shiner, longnose sucker, largescale sucker, and carp) generally spawn in late spring and early summer on rising water levels and usually dominate reservoir fish populations. Fisheries management for run-of-river reservoirs in the mid and lower Columbia and Snake rivers is concerned solely with the passage of anadromous salmonids. These downstream reservoirs are providing spawning habitat for an expanding population of exotic American shad. Entrainment loss of desirable reservoir fish populations can be minimized by selective water withdrawal, which is not common to most dams in the region.

SOME EFFECTS OF WATER-LEVEL FLUCTUATIONS ON WARMWATER FISH PRODUCTION IN SOUTHWESTERN RESERVOIRS WITH AN ASSESSMENT OF COMPENSATING MANAGEMENT STRATEGIES

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ABSTRACT

Reservoir operations in California, and the southwestern United States in general, are influenced by highly seasonal precipitation, most of which occurs from November through April. Such precipitation patterns normally require that water be stored in winter and spring and released in summer and fall. Seasonal variations in water storage are often enormous, and annual surface water-level fluctuations in excess of 30 m regularly occur among major irrigation reservoirs on the east side of California's Central Valley. Within-year reservoir fluctuations in other parts of California are usually less severe, although between-year variations in water storage are often substantial, particularly in portions of the state south of the Tehachapi Mountains.

Fluctuating water levels have their greatest impact on self-sustaining centrarchid segments of reservoir fisheries. While salmonid, ictalurid, and serranid population densities can often be enhanced by hatchery programs, popular centrarchid species such as largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and crappie (*Pomoxis* sp.) are traditionally managed as naturally reproducing resident populations. Adverse impacts of water-level fluctuations on centrarchids include physical disruption of the spawning-nest guarding sequence and the gradual loss of shoreline shelter (especially the finer components which are needed as escape cover for fry and fingerlings), a function of erosion and reservoir aging.

Various compensatory management strategies that have been used to

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overcome problems created by fluctuating water levels are examined. These include: (a) direct negotiation with agencies responsible for reservoir operations; (b) the maintenance stocking of hatchery reared largemouth bass; (c) the introduction of relatively deep nesting centrarchids such as Alabama spotted bass (*M. punctulatus henshawi*); and (d) the establishment of flood-tolerant vegetation in the fluctuation zone of reservoirs.

WATER-LEVEL FLUCTUATIONS AND FISHERIES MANAGEMENT IN THE SOUTHEAST

Ronald Pasch*

ABSTRACT

Fluctuating water levels in southeastern reservoirs have been viewed as both a significant problem and an extremely beneficial measure by fishery managers. These extreme viewpoints are to be expected from managers of so heterogeneous a collection of physical and biotic systems. Stable shallow reservoirs can benefit from extensive drawdowns to control vegetation that hampers access and fishing and adversely affects sport fish stocks. Extreme fall and winter drawdowns, followed by refilling in the spring, can stimulate expanding healthy fish stocks. Declining water levels during the spring spawning period can seriously affect subsequent recruitment to sport fish stocks. On the other hand, properly timed spring drawdowns can be used to suppress stocks of undesirable rough fish. Annual dewatering through summer months can lead to a sterile unproductive littoral zone resulting in poor growth and survival of fish, particularly young-of-year. Periodic modifications in reservoir operations (every five or six years) to allow revegetation of the fluctuation zone and/or surcharging is one means of mitigating the detrimental effects of annual dewatering.

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WATER-LEVEL MANIPULATION FOR THE ENHANCEMENT OF GAMEFISH PRODUCTION IN THE NORTHEAST UNITED STATES

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ABSTRACT

Water-level manipulation techniques and problems in the northeast were studied by making a telephone survey of fishery administrators in 19 states and an extensive review of the published literature.

The telephone survey revealed that the specific fishery management objectives cited for use of water-level control were (in order of frequency): control weeds, force forage fish out of cover to make them susceptible to predation, maintain appropriate levels during spawning for both fall and spring spawning fish, and decrease wild fluctuations in water level. Water-level manipulation was restricted by higher priorities for water supply to cities and industry, flood control, hydroelectric power production, and stable summer levels for recreational use. These restrictions limited drawdowns in almost every state to fall or winter seasons, but in Michigan even winter drawdowns were in conflict with ice skating and ice fishing. Power production and water supply were principal concerns for the most northeastern states, with flood control and summer recreational levels more important in many of the states further west and south.

The literature survey produced an annotated bibliography of 350 papers on water-level effects on lakes. Some additional techniques, which the survey identified, that could benefit specific target fish species were: pulse raises to encourage multiple spawning by forage fish; lowering of water level during carp spawning periods, combined with rough fish removal during drawdown; encouraging the production of terrestrial fauna for food by drawdown coupled with vegetation planting

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followed by inundation; and drawing the water level down slowly to maintain clean gravel bottoms through wave action in lakes with walleye. None of these techniques stimulates all possible game fish species, and seldom can more than one or two of them be implemented at one time in a lake even if there are no external constraints on water level.

Specific management techniques gave variable results from region to region. This is due in large part to the lack of studies to examine the underlying changes in forage of various types available under different water-level regimes. A great deal of information is yet required on the role of sediment exposure on nutrient release upon reflooding, the relative importance of detritus-based and autochthonous food supplies under different water-level regimes, the effects of water-level fluctuation on zooplankton populations, particularly during spawning seasons, etc.

NATIONAL OVERVIEW OF EFFECTS OF FLUCTUATING WATER LEVELS ON FISHERIES

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ABSTRACT

Although there are 9.3 million acres of natural lakes in the continental United States, exclusive of the Great Lakes, the majority of states contain little natural lake habitat. Nine states contain no natural lakes capable of supporting fish populations of interest to anglers. However, some 1,500 artificial impoundments over 500 surface acres in size, netting approximately 8.9 million acres of new aquatic habitat, have been built in the United States.

As each new impoundment is created, the confined aquatic communities rapidly expand to fill the sparsely populated habitat to carrying capacity. Uniquely, at this time, the entire prey biomass is comprised of organisms of available size to predators, and the entire lake carrying capacity of predators is contained in one or two year classes. These conditions result in exceptionally large initial yields and unexcelled fishing three or four years after impoundment. However, fewer reservoirs are being planned, and the fishing bonanza provided by new reservoirs will occur less frequently. One result is that management of existing reservoirs will become more important to sustain adequate angling opportunities. One management opportunity relates to water-level fluctuations.

High water levels during reproduction periods predictably result in enhanced reproduction of most fish populations as the expanded habitat is filled to carrying capacity by young fish. At Beaver Reservoir in Arkansas, the late-summer density of young-of-the-year black bass was correlated with increases in spring surface area over the previous winter surface area ($r = 0.66$, $p < 0.05$). However, relatively small

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year classes of young largemouth bass at Beaver Reservoir have produced exceptionally large crops of yearlings. Conversely, the largest crop of young largemouth bass (1978) produced the lowest number of yearlings in the history of the lake. Regression analysis shows no significant relationship between the number of young-of-the-year largemouth collected in August (1968-1978) and the subsequent number of yearlings collected the next spring ($r = -0.41$, NS).

Survival to age one, rather than reproduction success, appears to be the controlling factor. Reductions of water volume affect reductions in the biomass of important prey groups such as zooplankton, aquatic insects, and fish. Reductions of prey biomass during periods of active predator feeding may ultimately inflict food shortages upon the dependent predator populations. For young predator fish, food shortages reduce growth and body condition and thereby increase stress. Perhaps more importantly, shortages of alternate prey species intensify loss of young predators directly through predation by larger predators.

SUMMARIES OF VEGETATION, WILDLIFE, AND FISHERIES WORKSHOPS

VEGETATION WORKSHOP SUMMARY

As evidenced by the presented papers, much of the concern over water-level fluctuation in reservoirs stems from its effects on vegetation and the consequent effects on fish and wildlife. Where shorelines are denuded, animals are adversely affected through direct loss of food, cover, and spawning substrate and by increased turbidity resulting from erosion. Other possible effects relate to leaching of soils and losses of nutrient input through decomposition of organic matter. For these and other reasons, the loss or alteration of shoreline plant communities is often of major concern to persons involved in reservoir resource management.

The importance of shoreline vegetation has been recognized in the planning phase of many recently initiated projects. For example, one speaker described efforts to predict the impacts to vegetation of proposed lake-level regulation on Lake Champlain, and another mentioned the practice of selective preimpoundment clearing to retain water-tolerant species within the fluctuation zone. For the most part, however, research has focused on revegetating shoreline areas where plant communities have been largely eliminated by normal reservoir operations. Approaches taken toward revegetation have been varied, reflecting the diverse goals of the researchers and characteristics of the reservoirs.

Direct seeding of annual forage plant species is a wildlife management tool that has been used for some years. The research efforts described for the TVA system have provided data on the effectiveness of various seeding techniques, as well as identifying obstacles to successful plant establishment and documenting wildlife usage of revegetated areas. The principal drawbank of this approach is the need for annual reseeding of most types of shoreline habitats. Where small shallow impoundments are managed for waterfowl habitat, the perpetuation of annual plant communities may be promoted through water-level manipulation and mechanical soil disruption, as illustrated in the Missouri waterfowl food studies.

Attempts to establish perennial plant communities on reservoir

shorelines have concentrated largely on the identification of species capable of withstanding the extreme stresses generally encountered on such sites. Depending on the location and purpose of the reservoir, shorelines may be inundated for large parts of the growing season, then exposed to severe drying conditions for extended periods, or they may be inundated and exposed on a daily or weekly basis. Plant establishment and persistence threrfore will depend largely on flood and drought tolerance, but other stresses compounded by water-level fluctuation include scouring by ice and debris, soil erosion, wildlife depredation, cattle grazing, and accelerated leaching of essential plant nutrients. The researchers at this meeting who have been studying this problem take similar approaches to it. Work in California, Oregon, South Dakota,* and Texas has been directed toward screening perennial plant species for adaptability to the drawdown zone environment through literature review and experimental field plantings. In conjunction with this work, data have been collected on effective and efficient methods of plant collection, propagation, and maintenance.

During the workshop discussions, a number of points were made concerning the current state of revegetation research, the direction future research might take, and the implementation of research findings to alleviate some of the problems encountered on reservoirs throughout the country. There was general agreement that the basic experimental methods discussed above provide a reliable means of identifying potentially useful plant species. Selection of annual species for seeding is generally based on the food value for wildlife, while perennial plantings are designed more for their ability to establish and persist indefinitely. In order to screen perennials for this purpose, the following steps are generally followed:

1. Review the scientific literature and survey local plant communities to select candidate species. Typical selection criteria include flood and drought tolerance, appropriate climate, tolerance to specific water and soil characteristics,

* The WES also contracted a study on Lake Oahe on the Missouri River near Pierre, S. D., results of this study were to be presented at this workshop, but the invited speaker could not be present.

and value as a soil stabilizer or wildlife food, cover, or fish-spawning substrate. Native species are generally preferred, but when exotics appear desirable, they should be evaluated carefully to ensure that they are not potential pests in the area. This should be done in consultation with plant material specialists familiar with the species.

2. Field and laboratory investigations should be conducted to determine the ability of the species to survive under the conditions typically imposed on the reservoir shoreline. These may range in intensity from simple test-strip plantings on the shoreline to rigorous replicated experiments. Such plantings should be evaluated through several growing seasons at minimum. Where possible, detailed records on costs, propagation, and maintenance should be maintained.

3. Based on the test plantings, recommendations should be devised specifying methods for large-scale plantings. These should include such things as recommended species, elevational range, soil preparation and amendments, collection, storage and planting techniques, maintenance, and monitoring.

Although the methodology described above has proved effective in screening plant species for use in shoreline revegetation, only a limited amount of screening work has been done. The workshop participants reported that they have evaluated several hundred species to date, but obviously many more may be appropriate which have not yet been tested. In fact, reservoir conditions are so often unique that even species proven satisfactory on one reservoir should be reevaluated before being used on another. The question of species selection is open to a great deal more investigation. Mr. Countryman, for example, pointed out the potential value of hybrid individuals, which tended to be the most successful plants in the fluctuation zones he studied on Lake Champlain. It is probable that particular ecotypes exist in many species which are considerably more likely to succeed than the more widely available individuals of those species. Mr. Ternyik has taken advantage of this in his work. His collection and propagation techniques, developed over years of revegetation work, frequently include wide-ranging searches for robust plant populations growing in environments similar to those he is attempting to revegetate. These populations then serve as a source of propagules for introduction on the denuded site.

In summary, it has been demonstrated that a wide variety of approaches have been taken in the search for effective shoreline reveteta-tion techniques. Very promising methods have been identified and tested by various investigators, and a simple experimental screening approach has emerged that may be employed wherever perennial plant cover is desired. It is clear only a small fraction of the potentially useful species have been tested thus far, and new approaches to improve the species selection process and to increase propagation success are constantly emerging. Information on other possible plant species besides those mentioned in this report that could be used for reservoir revegetation purposes can be found in Whitlow and Harris (1979).* Whitlow and Harris (1979) also contains a broad literature review of flood tolerance in plants.

* Whitlow, T. H. and R. W. Harris. 1979. "Flood Tolerance in Plants: A State-of-the-Art Review," T.R. E-79-2, USAE Waterways Experiment Station, Vicksburg, Miss. 39180.

WILDLIFE WORKSHOP SUMMARY

Discussion of wildlife issues related to fluctuating reservoir water levels was centered on the establishment and maintenance of desirable plant species on substrates with appropriate flooding characteristics (depth and timing), with particular reference to the habitat requirements of waterfowl. Although it was recognized that management objectives will vary greatly from region to region and among reservoirs within a region, certain common goals were apparent.

It was generally agreed that reservoirs should be examined on a site-by-site basis in the process of developing management plans for shoreline fluctuation zones. For example, steep-sided shorelines would be much less conducive to development of waterfowl habitat than gradually sloping sites. On the other hand, if perennial woody cover for upland wildlife is desired, slope angle may be less important since only the uppermost (least flooded) zone would be likely to support a permanent plant community. Other site factors that may be of interest include the proximity and nature of croplands, the possibility of managing adjacent agricultural lands specifically for wildlife, and the potential for physically modifying the shoreline to produce high-quality habitat (e.g., patchiness).

Accepting that wildlife habitat may be improved along denuded shorelines under certain conditions, the workshop participants turned their attention to the subject of subimpoundment management. The Missouri work reported by Drs. Frederickson and Sayre demonstrated that small impoundments can be very effectively manipulated to produce high-quality waterfowl habitat. Much of the success of this technique is derived from the lack of competing interests; that is, water depths, flooding, and drawdown dates, etc., can be specified without reference to the schedules imposed by power production, flood control, or other authorized objectives of a large multipurpose reservoir. The principal problems associated with such intensely managed areas are initial construction costs and annual pumping costs.

The high cost of construction and maintenance of small impoundments

can be reduced by taking advantage of existing conditions or project features. For example, small fingers of reservoirs may be diked off from the main lake, or existing beaver ponds or dewatering basins may be developed to increase habitat quality. Pumping costs may be reduced or eliminated by taking advantage of irrigation return flows or simply by siting impoundments to make full use of runoff. This latter system may include construction of a storage impoundment to serve as a source of water for the managed impoundment, using gravity flow rather than pumping when water is required. Where a number of subimpoundments or satellite impoundments are available, they may be managed in series; that is, some may remain flooded throughout a given year to retard development of woody perennials, while others are drained at the appropriate time to encourage growth of annuals. Perhaps the simplest approach may be to erect small dikes to create shallow basins and allow the system to function without regular management. Such areas would simply be allowed to fill by runoff and drain or evaporate at their own rate. Periodic removal of undesirable woody growth may be necessary in some instances.

Whatever approach is used, it was generally agreed that habitat improvement on or near reservoirs with fluctuating water levels is highly desirable and technically feasible, particularly with respect to waterfowl. In some cases, caution should be taken to avoid interfering with regional wildlife management goals (e.g., shortstopping migrating waterfowl). In general, however, it appears that a variety of options are available for improving project-area habitat.

FISHERIES WORKSHOP SUMMARY

A large percentage of the participants in the fisheries workshop were directly involved in reservoir fisheries management. Formal presentations and working sessions therefore addressed management problems. These included topics such as conflicts among reservoir users and techniques for managing reservoir fisheries. The fisheries workshop summary reflects the applied approach.

Important Problems and Ongoing Research and Management

The regional presentations and subsequent working sessions pointed out the extreme variability in physical, biological, and operational characteristics of reservoirs. This variability, when coupled with uncontrolled environmental influences, has made predicting responses of reservoir fish communities to fluctuations in water level very difficult. Many widely used techniques have evolved from general management observations and documentation with little emphasis being placed on evaluation of cause-and-effect mechanisms. Plans for water-level fluctuation frequently must be developed on a site-by-site basis, and there are substantial regional differences in management strategies. In spite of the high degree of individuality, most water-level management plans are based on a fairly limited number of basic concepts as defined in the following section.

Manipulation of water levels to enhance fisheries is usually based on the timely flooding or dewatering of vegetation. Where seasonal flooding of shoreline vegetation is recommended, fishery management plans may include lowering of water levels during a portion of the growing season to permit regrowth of vegetation. Fishery agencies frequently seed dewatered areas to enhance revegetation.

Water-level management in fluctuating warmwater and coolwater reservoirs generally involves raising water levels during the spring to enhance spawning and early survival of young predators. Pool levels are lowered during the summer to permit regrowth of vegetation in the

fluctuation zone. Fluctuations may be timed to benefit one or more target species; therefore, numerous variations occur. Evaluation is difficult and expensive; consequently, quantitative or incremental data are limited. In the central United States, managers frequently recommend small increases in pool levels during the autumn for waterfowl management.

Fall and winter drawdown is often recommended for shallow reservoirs that support large stands of aquatic macrophytes. The method is effective in concentrating prey species and controlling aquatic vegetation. Drawdowns that reduce surface area by as much as 50 percent are desirable. As with other basic approaches to water-level management, numerous variations have been proposed. For example, reduced fall-winter drawdown has been used in some flood control reservoirs to minimize downstream loss of fish.

Periodic major drawdown has been used effectively by some fisheries managers. This procedure involves drastic lowering of a reservoir pool level over an extended time period (at least one growing season) to permit vegetative regrowth in the dewatered zone. This may be augmented by seeding of plants such as sorghum and Japanese millet. The fish community may be selectively removed or killed completely. The reservoir is refilled during the spring; fish are restocked; and a high water level is maintained through the summer. The technique is effective for stimulating production of desirable sport and prey fishes, but if it conflicts with authorized reservoir purposes, it may be difficult to implement.

Water-level management in coldwater reservoirs is strongly oriented toward the production and enhancement of salmonids, with anadromous species receiving primary consideration. Important management problems relating to production of salmonids include maintaining access to tributary streams for spawning, controlling releases to facilitate passage of anadromous species, limiting losses of important sport fishes, and stabilizing reservoir pool levels during the extended periods of egg and larval development of certain species. Flooding of shoreline vegetation is not a primary consideration in the management of coldwater fishes.

Reservoir design, mode of operation, and specific life history requirements of target fishes play a primary role in determining water management strategies.

Participants at the fishery workshop identified conflicts with authorized reservoir uses as an overriding constraint to the use of water-level fluctuation for fisheries management. A lack of uniform guidance for dealing with the problem of water level control was also recognized.

Suggestions For Future Research

Several promising management approaches were presented during the workshop. Many limitations to our understanding of the complex physical, chemical, and biological interactions associated with fluctuating reservoir water levels were also identified. Additional research will be needed to better define cause-and-effect mechanisms and incremental response of fish communities to changes in reservoir pool levels. Studies should address interactions with lower trophic levels, behavioral and related life history effects, and interactions among complex predator-prey assemblages. Hypothesis testing and controlled experimentation will be required to identify and quantify the many important biological, chemical, and physical interactions associated with fluctuating reservoir water levels. Because of the many operational constraints and influences of uncontrolled environmental factors, studies will require careful planning and close cooperation between reservoir operators and fishery managers. Many studies will require several years to assess effects of environmental influences. With recognition of the above considerations, the following research needs are identified:

1. Quantify relations between flooded vegetation and selected reservoir fishes. Although not considered of great importance in many coldwater reservoirs, flooding or dewatering of vegetation is an essential element in the management of water levels for warmwater and coolwater fisheries. Its contribution as substrate for reproduction of certain fishes, escape cover for prey and young predators, production of

lower trophic levels, and stabilization of shoreline habitat makes establishment and maintenance of vegetation an essential part of water-level management. Research is needed for better definition of flood tolerances and regeneration times of important fluctuation zone plants, identification of additional plant species adapted to environmental conditions in the fluctuation zones, and description of incremental relations between flooded vegetation and important life history stages of fishes.

2. Determine effects of water-level fluctuation on the life history of target fishes. Water-level manipulation is often recommended to enhance reproduction and early survival of important predator or prey species. Cause-and-effect relationships remain poorly understood, however, and managers frequently rely on seasonal control of water levels to obtain fishery objectives.

Case-history data needed for efficient management of water levels in the Columbia basin have been obtained from the results of experiments designed to document the effects of water-level fluctuations on the early life history stages of salmonids in reservoirs of the northwestern United States. Similarly, intensive studies to quantify effects of water-level fluctuations and associated flooding of shoreline vegetation on specific life history stages of important coolwater and warmwater fishes would (a) aid managers to communicate fisheries needs to reservoir operating agencies and (b) enable fisheries biologists to fine tune plans for water-level management.

3. Clarify the role of predator-prey interactions in determining year class strength of predator fishes in reservoirs. Norville Prosser, in summarizing the fisheries portion of this workshop, postulated that availability of prey was the most important factor determining year class strength of some important predator species. He suggested that benefits of controlled reservoir levels to enhance predator reproduction could be negated by subsequent deficiencies of available prey or cover. His hypothesis is supported by long-term studies by the National Reservoir Research Program on largemouth bass recruitment under variable patterns of water-level fluctuation in Beaver and Bull Shoals Lakes,

recent studies of largemouth bass populations of several southern reservoirs, and studies on northern pike in the Great Plains.

A well-planned research thrust to provide definitive answers concerning the role of available prey in determining year class strength of important predators would substantially change current water-level management strategies. For example, recommendations for seasonal control of water levels would certainly be altered by a change in emphasis from predator to prey enhancement. Management of water levels to enhance reproduction of gizzard shad requires flooding of shoreline vegetation into the summer, whereas high water levels are needed during early spring to enhance reproduction of certain predators such as walleye, northern pike, and largemouth bass.

4. Determine responses of primary and secondary trophic levels to flooding. An understanding of the relations between flooded terrestrial vegetation and production of invertebrates and periphyton is important in planning water-level control for fisheries management. More efficient use of reservoir water-level control for fisheries management could be developed based on the results of studies to define colonization rates of periphyton and invertebrate communities on flooded vegetation, responses of these communities to decomposition of flooded vegetation, and their use by small fishes.

5. Evaluate the potential of subimpoundments for enhancing reservoir fishery resources. Legal, operational, and environmental constraints limit opportunities for water-level control in many impoundments. Construction of small intensively managed subimpoundments was recognized as an alternative means of obtaining fishery benefits. Before managers can use this alternative technique effectively, research is needed to identify and resolve conflicts with wildlife management objectives, determine optimum design characteristics, establish cost and economic benefits, and define operational needs.

6. Develop integrated approaches to the management of fishery resources within large river basins. Most large U. S. rivers are impounded at numerous locations, and operation of reservoirs for authorized purposes is carefully coordinated. Fishery needs are usually

approached on a site-by-site basis. In several large reservoir-river systems such as the Columbia, Missouri, and Tennessee basins, fishery needs are included in annual operational plans. Unfortunately, most reservoir-river systems do not have this flexibility. The development of models relating water-level needs for fisheries to other uses in chains of reservoirs could provide a relatively inexpensive means to explore management options. Of particular interest would be the modified operation of reservoirs within major portions of a river basin to facilitate extreme drawdown of selected impoundments on a periodic (3 to 5 years) basis. Workshop participants generally agreed that major changes in water levels had a greater impact on fish populations. Unfortunately, major drawdowns are very difficult to justify when reservoirs are operated singly. By considering the integrated use of all reservoirs within large portions of major drainage basins, additional opportunities for fisheries management should be apparent.

7. <u>Establish long-term ecological investigations to define processes associated with reservoir aging and the effects of natural environment fluctuations on reservoir fisheries.</u> As construction of reservoirs slows, resource managers face the formidable task of maintaining acceptable fisheries in aging reservoirs. While declines in fisheries with reservoir aging have been well documented, causal mechanisms remain poorly understood. Uncontrolled environmental variation may mask effects of aging unless studies extend over a period of years. Costs for conducting long-term ecological studies are high, and it has been difficult for fish and wildlife agencies to justify studies needed to quantify these relations. Long-term (10 to 20 years) ecological studies on a small number of reservoirs with various morphometry and use types would supply the needed case-history information.

8. <u>Develop standardized measures for reservoir fishery benefits.</u> Most large public works projects are authorized for multiple uses. When fishery needs are addressed, they must be evaluated relative to other reservoir uses. Monetary values have proven unsatisfactory for comparing fishery benefits. Recently, measures such as usable habitat, biomass, or abundance have been used with limited success on some projects;

however, additional research is needed to develop acceptable units of measure for comparison with other reservoir uses.

Operational and Administrative Barriers

Participants at the fisheries workshop session considered conflict with authorized reservoir uses as a primary obstacle to the use of water-level control for fisheries management in reservoirs. Enhancement of fishery resources is not an authorized purpose at many reservoir projects, and authorization requires congressional action. When authorization is obtained, costs for water allocated to fishery benefit are considered reimbursable unless they are for mitigation. Monetary values assigned to fishery benefits have historically been low as compared to other reservoir uses. This makes cost sharing for reallocation of storage prohibitive to many fishery agencies. Most large public works projects are designed for multiple uses, and coordination between two or more agencies is required to change operation. A lack of general guidance concerning operating constraints complicates interactions between fishery management and reservoir operating agencies.

In spite of the numerous operational constraints and lack of overall guidance concerning water-level control, authorized project purposes frequently contain enough flexibility to permit some manipulation of water levels for fisheries management. This varies greatly among projects, but a few generalizations seem appropriate. Upstream reservoirs in a series or a single reservoir on a watershed offer fewest opportunities for water-level control. Opportunities for modification of reservoir operation increase with complexity of a reservoir-river system, and become greatest in large river basins such as the Columbia, Missouri, Tennessee, lower Ohio, and Colorado where operation of reservoirs within large portions of the basins are highly integrated. Reservoirs operated primarily for flood control generally provide greater opportunity for water-level management than hydropower projects.

Ideally, fish and wildlife benefits should be incorporated during early project planning stages. However, when it appears desirable to

modify water levels at existing projects, a fishery agency should present justification for a specific operational change. This should include carefully defined objectives supported by hard data, if possible. Objectives should be given priorities, and trade-offs carefully developed in advance. Acceptable levels of probability for success of a management request should be communicated. A plan incorporating both fish and wildlife interests will usually be more favorably received than one reflecting a narrow perspective.

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